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Mining & Metals + Internet of Things: Industry opportunities and innovation

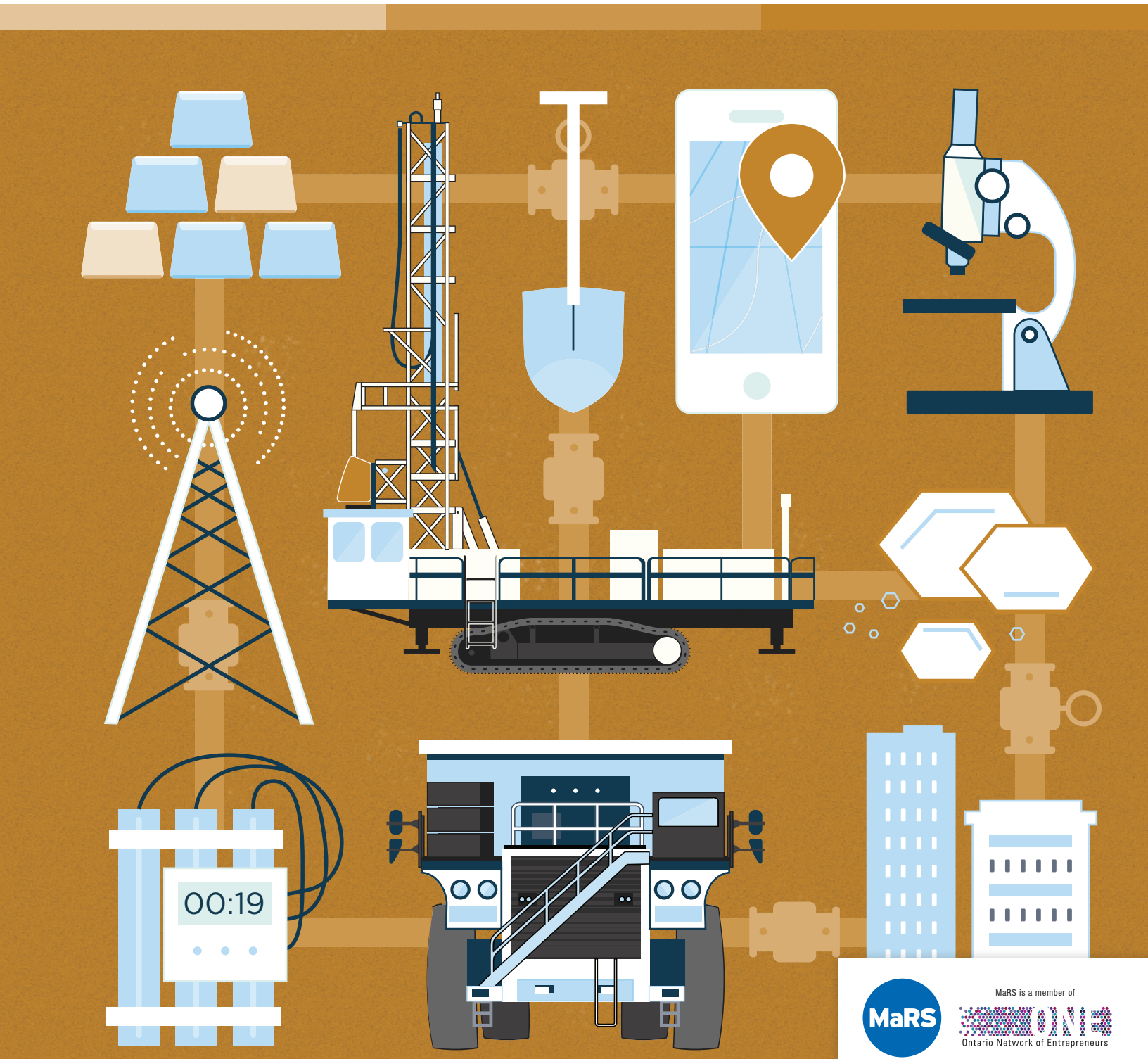

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Table of Contents

TABLES AND FIGURES

Introduction

The mining industry is as vital to today's global economy as ever before, yet it is at a crossroad. It is an industry that is currently combating multiple adverse global trends such as falling commodity prices, a slowing global economy and skilled labour shortages. In an September 2014 interview for this report, Glenn Ives, Americas Mining Lead and Chairman of Deloitte Canada, observed that while the industry over the last year or two had "gone down—there is a realization that we do need minerals to keep our economies going." The shift toward technology will actually also increase our dependence on mining. The industry, for the most part, understands what must be done. "Mining innovation is moving ahead," argues Ives. The World Economic Forum highlighted "automation of operations" as a top technological driver identified by global mining stakeholders.[1]

If mining automation is the "poster child" of mining innovation, then the Internet of Things is arguably the "printing press." Indeed, by enabling the Internet of Things (IoT), miners could unlock benefits beyond mining automation and enhance existing or new information technology products and services.

The calls for innovation in the mining industry are deafening, and the IoT is making its way into mining sites. For entrepreneurs who want to sell their IoT-based solutions to the industry and help miners address challenges, this is music to their ears. Or is it?

Mining is an industry with great traditions where change is at times very gradual. As Dr. Joerg Benndorf, Assistant Professor of Resource Engineering at Delft University of Technology in the Netherlands, reminds us, mining is a very old business and it can be reluctant to embrace new technology. It is difficult to leave behind a suite of tried-and-true processes when you are focused on production and profits. More often than not, the adoption of new technology, just like the adoption of any new process in the mining industry, has to improve the bottom line or meet a mandated requirement.

For this report, which is part of the Connected World Market Insights series, the MaRS Market Intelligence team interviewed multiple stakeholders in the mining community in order to examine the intersection of mining and the IoT. The beginning of the report highlights some of the current macro trends in mining. Then we discuss the IoT and its related applications within the mining sector. We later broaden the focus to Canada and look at how the Canadian mining industry is responding to opportunities to innovate. In closing, we discuss Canada's innovation advantages, examples of key innovators and industry recommendations for entrepreneurs.

At the end of the report, we feature seven profiles of key companies innovating mining technology.

Industry trends and challenges: Highlights

Boom, bust and China: It's all about prices

Throughout much of the last century, "mining was a low-growth business," says Andrew Mackenzie, CEO of BHP Billiton, a global mining giant based in Australia.[2] Though after a period of stagnant prices (1980s and 1990s), commodity prices grew in a stunning fashion due to a mix of housing construction boom, commodity speculation, pro-growth economic policies and a seemingly insatiable demand from developing countries, especially China. Collectively, Mackenzie believed that the industry was "caught off-guard by the pace of China's early 21st-century urbanization and industrialization."[3] In a purely economic sense, increasing prices and ever higher demand for minerals and metals signalled to miners that they should increase their supply. This boom was hailed by many as the commodities' "supercycle."

As of the end of 2014, a certain trend in commodity prices over the last few years is abundantly clear. Since 2011, prices have trended downward (see Figure 1). While some banks, such as JP Morgan, still believed that the supercycle trend was intact in early 2013, other major banks such as Citigroup Inc., Deutsche Bank and Goldman Sachs Inc. all published research notes calling an end to the supercycle by mid-2013.[4,5] In fact, as recently as September 2014, Goldman Sachs Inc. published a new research note declaring "the end of the Iron Age," where it argued that the mining industry would move from an old period of over-investment to a new period of exploitation.[6]

Table 1: Commodity Pricing Movement (2009 to 2014)

SELECTED PRECIOUS METALS

GOLD (COMEX) HISTORICAL PRICING

10/1/2009*	10/1/2013	4/1/2014	7/1/2014	10/1/2014
$1,000.70	$1,286.10	$1,280.00	$1,326.60	$1,215.60

HIGHEST PRICE DATE (OCT 2009 TO OCT 2014)	HIGHEST PRICE IN PERIOD
8/22/2011	$1,889.70

CHANGE SINCE HIGHEST PRICE IN PERIOD	CHANGE IN 3-MONTHS	CHANGE IN 6-MONTHS	CHANGE IN 12-MONTHS
-36%	-8%	-5%	-5%

SILVER (COMEX) HISTORICAL PRICING

10/1/2009*	10/1/2013	4/1/2014	7/1/2014	10/1/2014
$16.44	$21.18	$19.69	$21.12	$17.26

HIGHEST PRICE DATE (OCT 2009 TO OCT 2014)	HIGHEST PRICE IN PERIOD
4/29/2011	$48.60

CHANGE SINCE HIGHEST PRICE IN PERIOD	CHANGE IN 3-MONTHS	CHANGE IN 6-MONTHS	CHANGE IN 12-MONTHS
-64%	-18%	-12%	-18%

SELECTED NON-PRECIOUS METALS

ALUMINUM CASH (LME) HISTORICAL PRICING

10/1/2009*	10/1/2013	4/1/2014	7/1/2014	10/1/2014
$1,824.00	$1,779.90	$1,754.75	$1,854.25	$1,888.40

HIGHEST PRICE DATE (OCT 2009 TO OCT 2014)	HIGHEST PRICE IN PERIOD
4/29/2011	$10,179.50

CHANGE SINCE HIGHEST PRICE IN PERIOD	CHANGE IN 3-MONTHS	CHANGE IN 6-MONTHS	CHANGE IN 12-MONTHS
-32%	2%	8%	6%

COPPER CASH (LME) HISTORICAL PRICING

10/1/2009*	10/1/2013	4/1/2014	7/1/2014	10/1/2014
$5,967.50	$7,174.00	$6,665.00	$7,039.50	$6,729.75

HIGHEST PRICE DATE (OCT 2009 TO OCT 2014)	HIGHEST PRICE IN PERIOD
2/14/2001	$10,179.50

CHANGE SINCE HIGHEST PRICE IN PERIOD	CHANGE IN 3-MONTHS	CHANGE IN 6-MONTHS	CHANGE IN 12-MONTHS
-34%	-4%	1%	-6%

IRON ORE 62% FE
(NYMEX) HISTORICAL PRICING

10/1/2009*	10/1/2013	4/1/2014	7/1/2014	10/1/2014
$129.38	$127.43	$116.67	$95.12	$78.88

HIGHEST PRICE DATE (OCT 2009 TO OCT 2014)	HIGHEST PRICE IN PERIOD
8/13/2013	$138.75

CHANGE SINCE HIGHEST PRICE IN PERIOD	CHANGE IN 3-MONTHS	CHANGE IN 6-MONTHS	CHANGE IN 12-MONTHS
-43%	-17%	-32%	-38%

LEAD
CASH (LME) HISTORICAL PRICING

10/1/2009*	10/1/2013	4/1/2014	7/1/2014	10/1/2014
$2,163.50	$2,037.30	$2,020.50	$2,131.25	$2,083.00

HIGHEST PRICE DATE (OCT 2009 TO OCT 2014)	HIGHEST PRICE IN PERIOD
4/11/2011	$2,938.90

CHANGE SINCE HIGHEST PRICE IN PERIOD	CHANGE IN 3-MONTHS	CHANGE IN 6-MONTHS	CHANGE IN 12-MONTHS
-28%	-2%	3%	2%

*Note: iron price data on NYMEX started on 5/13/2013 Source: S&P Capital IQ

SELECTED NON-PRECIOUS METALS

NICKEL

CASH (LME) HISTORICAL PRICING

10/1/2009*	10/1/2013	4/1/2014	7/1/2014	10/1/2014
$17,348	$13,675	$15,042	$19,042	$16,019.5

HIGHEST PRICE DATE (OCT 2009 TO OCT 2014)	HIGHEST PRICE IN PERIOD
2/21/2011	$29,029.00

CHANGE SINCE HIGHEST PRICE IN PERIOD	CHANGE IN 3-MONTHS	CHANGE IN 6-MONTHS	CHANGE IN 12-MONTHS
-45%	-16%	0%	17%

TIN

CASH (LME) HISTORICAL PRICING

10/1/2009*	10/1/2013	4/1/2014	7/1/2014	10/1/2014
$14,690.00	$23,010.00	$22,972.00	$22,795.00	$20,308.00

HIGHEST PRICE DATE (OCT 2009 TO OCT 2014)	HIGHEST PRICE IN PERIOD
4/11/2011	$33,255.00

CHANGE SINCE HIGHEST PRICE IN PERIOD	CHANGE IN 3-MONTHS	CHANGE IN 6-MONTHS	CHANGE IN 12-MONTHS
-39%	-11%	-12%	-12%

SELECTED NON-PRECIOUS METALS

ZINC

CASH (LME) HISTORICAL PRICING

10/1/2009*	10/1/2013	4/1/2014	7/1/2014	10/1/2014
$1,886.00	$1,840.00	$1,962.25	$2,179.50	$2,261.50

HIGHEST PRICE DATE (OCT 2009 TO OCT 2014)	HIGHEST PRICE IN PERIOD
1/7/2010	$2,634.40

CHANGE SINCE HIGHEST PRICE IN PERIOD	CHANGE IN 3-MONTHS	CHANGE IN 6-MONTHS	CHANGE IN 12-MONTHS
-14%	4%	15%	23%

SELECTED ENERGY

CRUDE OIL

LIGHT (NYMEX) HISTORICAL PRICING

10/1/2009*	10/1/2013	4/1/2014	7/1/2014	10/1/2014
$70.82	$102.04	$99.74	$105.34	$90.73

HIGHEST PRICE DATE (OCT 2009 TO OCT 2014)	HIGHEST PRICE IN PERIOD
4/29/2011	$113.93

CHANGE SINCE HIGHEST PRICE IN PERIOD	CHANGE IN 3-MONTHS	CHANGE IN 6-MONTHS	CHANGE IN 12-MONTHS
-20%	-14%	-9%	-11%

Source: S&P Capital IQ

Amid the volatility of commodity prices, China's economy has finally shown signs of slowing, which should limit China's demand for metals and minerals overall. This should be alarming to many iron ore producers, as China buys about 66% of all seaborne iron ore. However, further proving that the industry is in a state of flux, supply for commodities such as iron is set to grow twice as fast as demand, almost guaranteeing continued downward pricing pressure and a negative impact on profit margins.[7] Almost of all of the industry stakeholders contacted for this report characterized the mining industry as an industry experiencing a downturn.

Unless the current economic challenges of the global mining industry change for the better, many of the trends seen in 2014 will likely continue. Ives explains, "I don't think any of the trends have reversed. They're heading, directionally, in the same way, but perhaps not all at the same speed. You're seeing some of them that are becoming more important, some of them less."

Table 2: Top 10 Trends in Mining 2014

TRENDS	ISSUES	TRACKING TRENDS THEMES
1	**Productivity issues**	The cost of contraction
2	**Price issues**	Matching supply to demand
3	**Innovation issues**	Remaking mining
4	**Financing issues**	Finding funding
5	**Capital allocation issues**	The project pipeline stutters
6	**Community issues**	Power to the people
7	**Government relations issues**	Resource nationalism spreads
8	**Regulatory issues**	Crackdown on corruption
9	**Safety issues**	Changing the safety equation
10	**Labour issues**	A dearth of skills

Source: Deloitte[8]

Key industry challenges

In addition to changing prices, three key challenges are affecting the industry. These are outlined below.

MINING OPERATIONAL CHALLENGES

"Our ores, near-surface ores, are getting to be depleted, so we need to go further down," says Vic Pakalnis, President of MIRARCO Mining Innovation and Director of the Mining Safety Risk Management Centre. All else being equal, the more miners extract from current deposits, the more difficult and expensive mining will become. "The average grade of the deposits continues to decrease," observes Ives. Miners will increasingly have to deal with the prospects of mining low-grade ores and turn to "more remote destinations and deeper deposits."[9] Andy Reynolds, General Manager of Energy, Mining and Environment at the National Research Council Canada (NRC), argues that not only will low-grade ore act as a real driving factor, but the implication will be profound and will impact all aspects of technology, as well as operational, commercial, and investor relationships. "Mining companies will have to make decisions based on how efficiently their competitors can extract metals and minerals. If these companies want to operate and make money, they are going to have to be able to extract metals and minerals at a lower cost," Reynolds explains.

A DOWNTURN IN EXPLORATION AND THE JUNIORS MARKET

Exploration activities have been hard hit at this stage of the supercycle, and this has particularly affected mining juniors and the exploration markets. Just how hard hit was that part of the market? Consider the following statistic: the market capitalization of the top 100 junior miners on the TSX Venture Exchange fell a whopping 44% in 2013 when compared to 2012.[10] Dick DeStefano, Executive Director of the Sudbury Area Mining Supply and Service Association (SAMSSA), a trade association based in Sudbury, Ontario, puts it bluntly. "Junior mining exploration is dying. Junior miners are giving away their findings for peanuts to major companies. They drill and then they stop, because they don't have any money, because they are one of 50 in the marketplace." The prior over-investment and current lack of exploration will undoubtedly have some undesirable long-term impact in the future if this trend continues. Perhaps this is one of the reasons why, in September, 2014, the Northwest Territories government gave close to $400,000 to six mining juniors in order to encourage them to continue their exploration work through a new fund called the Mining Incentive Program.[11] This is unlikely to solve the problem for Canada, but the downturn does indicate that when new mineral resources are needed again, the industry is going to need more productive and lower-cost methods to identify and quantify deposits.

INFORMATION TECHNOLOGY DEPLOYMENT AND INNOVATION

Divergent industry views and experience with respect to information and communication technology (ICT) deployment and innovation are clear to see.

On the one hand, enough data exists to suggest that mining companies are beginning to take ICT seriously. Total ICT spending in the global mining sector is projected to increase from US$16.3 billion in 2010 to US$26 billion in 2018, growing at a compounded annual rate of 5.4%.[12] The main drivers cited for such "rapidly" increasing ICT spending are similar to those for the trends and challenges discussed above. The IoT will grow at least 10 times faster than the overall ICT sector in Canada.[13]

C. Prasanna Venkatesan, Business Development Lead for Internet of Things Group in Mining at

Cisco, told us that business has been growing at a very healthy rate for a while. Mining companies are increasingly deploying IoT solutions to improve their operating environments. These solutions range from Big Data analytics for predictive maintenance to digital tailings monitoring for operational safety to ventilation controls to reduce costs and their energy footprint. Pakalnis recalls that the CEO of Anglo American, Mark Cutifani, urged everyone to do better in innovation for the survival of the mining industry.

Yet, on the other hand, the industry climate is so harsh that innovation could well be threatened. Based on the current commodity cycle, Reynolds believes that it is "very difficult for [mining companies] to identify spare cash for traditional R&D activities." Dr. Omid Mahabadi, co-founder of Geomechanica, agrees that "they're not looking to new things—they're just trying to [organize] themselves and get back on their feet again." Geomechanica is not the only Canadian company finding that serving the mining industry has its challenges. Kirk Petroski, President and CEO of Symboticware Incorporated, echoes this belief, saying, "We're really dealing with small cycles. It's hard, and it's a barrier to develop new technology in a very short-cycled market because there's no uptick for adoption at a certain point."

Our research will explore how the mining sector could adopt the most tried-and-true and up-and-coming IoT technologies, especially once the exploration and planning cycles recommence.

What is the Internet of Things?

The introduction of this report posits the Internet of Things (IoT) as the "printing press" of mining innovation. Clearly, vast as it is, the IoT is transforming many domains. This report looks at the role of the IoT in the context of mining. While a full IoT primer is not the goal of this report, we do offer some historical context. We explore mining IoT and its protocols, and examine its benefits and applications in mining.

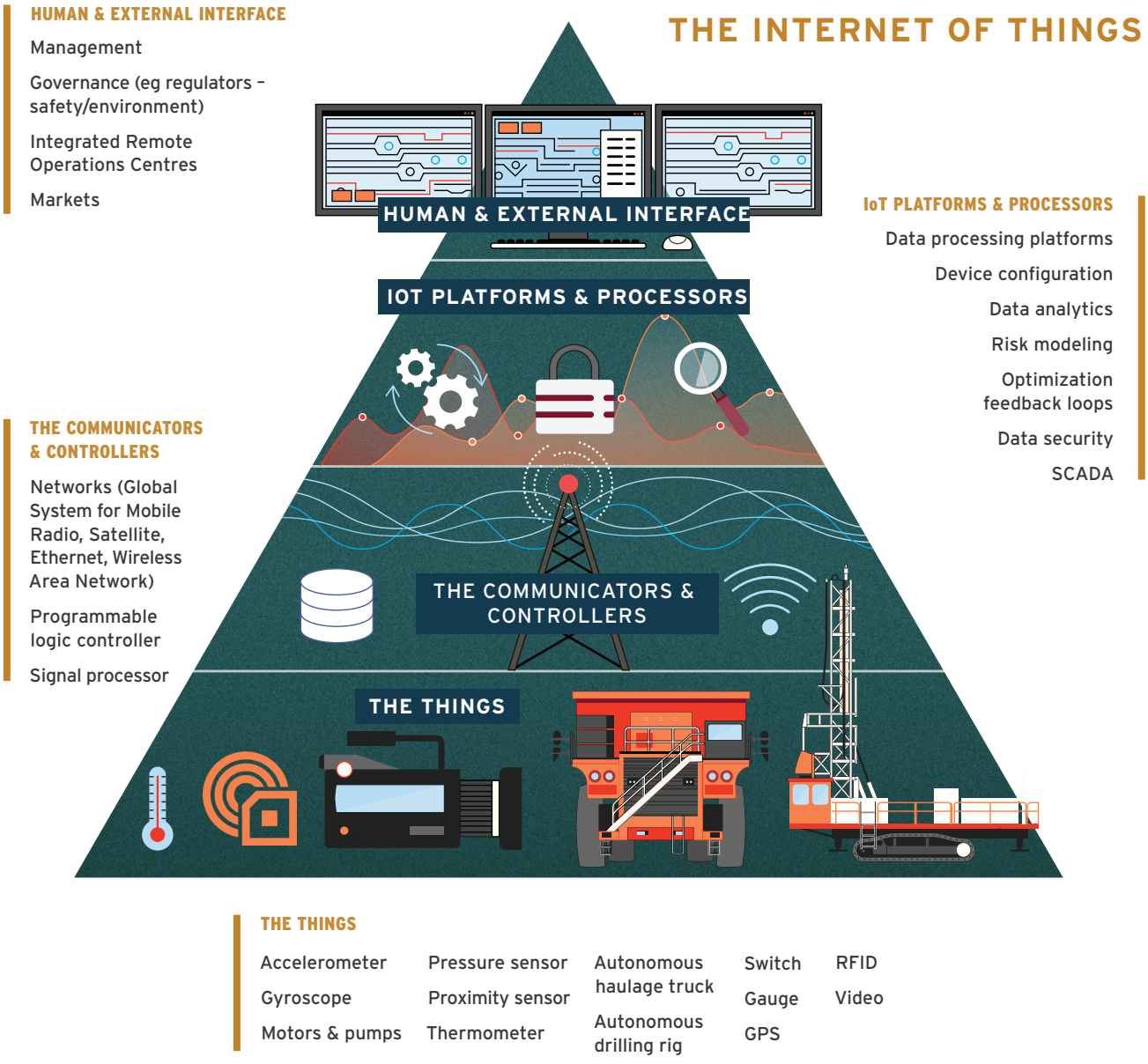
Some skeptics, especially those with a background in industrial equipment, have wondered aloud if anything is new, especially when much of the IoT discussion is coupled with automation. The industry has been deploying programmable logic controller (PLC) and supervisory control and data acquisition (SCADA) systems for industrial processes and automation for years, including at mine sites. However, despite the complexity of these systems, they were never quite designed to communicate with each other or within a larger system.

As Graham Churchill, Canadian Mobile First & IoT Software Leader at IBM, observes, changes are beginning to happen. "What you see today is a world where, particularly in SCADA systems and so forth, companies will try to build complete solutions. And if you want to get any of the data out of that, you've got to write proprietary programs to get at the data. Typically, you'd only get a part of it. What's happening in the marketplace is that we're starting to see the formation of web services or open standards for industrial equipment and industrial communications," says Churchill. In many ways, the evolution of technology uptake in mining control systems shows a parallel with the changes the IT industry saw in the past 20 years.

A simple definition of the IoT is the connection of objects such as computing machines, embedded devices, equipment, appliances, and sensors to the Internet. Many of these machines do not have recognizable computing parts such as a touchscreen or a monitor, leading some to call the machines "headless" IoT devices. Indeed, the likelihood of "headless" may well be a way to differentiate the consumer side of the IoT with the industrial side.

Beyond connectivity, the other major keys are (real-time or near real-time) data and analytics, especially Big Data solutions (see Figure 1). "The Internet of Things is all about the combination of data from many different sources and being able to gain insights and interactions as a result of bringing those things together," states Churchill.

Figure 1. The Internet of Things technologies in mining



Technology market data

GLOBAL ICT (OVERALL)[I]

MINING

US$16.3B (2010)

FORECAST US$26.1B BY 2018

GLOBAL RFID[II]

OIL & GAS

US$175M (2010)

CAGR 26.5%

FORECAST US$1,018.7M BY 2017

GLOBAL AUTONOMOUS MINING EQUIPMENT[III]

MINING, OIL & GAS

US$361M (2014)

CAGR 10.7%

FORECAST US$600M BY 2019

NORTH AMERICA M2M[IV]

MINING

US$11.1M (2014)

GLOBAL SCADA[V]

ALL

US$5,426.2M (2011)

CAGR 7.1%

GLOBAL PLC[VI]

MINING, OIL & GAS

US$155.8M (2013)

CAGR 7.1%

AUTOMATED HAUL TRUCKS COST APPROXIMATELY US$6 MILLION EACH.[III]

AUTOMATED HAUL TRUCKS MAKE UP ALMOST 90% OF AUTONOMOUS MINING EQUIPMENT.[III]

Sources:

I Frost & Sullivan, 2014. Industry Scorecard for the Global Mining Industry
II Frost & Sullivan, 2012. Analysis of the RFID Market in the Oil and Gas Industry
III BCC Research, 2014. Smart Machines: Technologies and Global Markets
IV Frost & Sullivan, 2012. Analysis of the North American M2M Software and Services Market
V Frost & Sullivan, 2013. Strategic Analysis of the Global SCADA Market
VI Frost & Sullivan, 2014. Global Programmable Logic Controllers Market

Select Fortune 500 company visions of the IoT in industrial applications

Cisco	**"Internet of Everything"; "latest wave of the Internet—connecting physical objects… to provide better safety, comfort and efficiency"**
IBM	**"A completely new worldwide web, one comprised of the messages that digitally empowered devices would send to one another. It is the same Internet, but not the same Web"**
GE	**"Industrial Internet"; "the convergence of machine and intelligent data"; "brilliant machines"**

Source: Cisco,[14] Readwrite,[15] MIT Technology Review,[16] Electronic Design[17]

The fact that these companies stressed that IoT is at least somewhat of a different type of Internet is compelling. There are differences between the Internet that consumers know and the Internet that makes machines smart both conceptually and technically.

Graham Churchill says that the World Wide Web was designed to "enable the delivery of content in the form of documents to websites. It was always envisioned that there would be somebody at the end of this screen, so that if something didn't get delivered properly, they would be able to refresh it." Hence, HTTP (hypertext transfer protocol) was created. "The Internet of Things is based on the concept of events," explains Churchill, "and there are so many different types of devices that you would have to go look at, you can't be pulling information [manually]."

Arlen Nipper, co-inventor of the machine-to-machine connectivity protocol (MQTT) and co-founder of Cirrus Link Solutions, frames the advantage of his invention as a messaging middleware that was built to decouple devices from SCADA system implementations, while still providing "mission-critical" SCADA functionality. The results satisfies all of the operational SCADA functionality in real time while still providing access to all of the additional "non-mission critical" information that intelligent devices offer today. This is significant as current SCADA system implementations omit the non-mission critical information and as a result, MQTT is positioned as a key IoT protocol in the enterprise and industrial world.

Table 3 compares MQTT with other prominent IoT protocols.

Table 3: Selected Internet of Things Protocols

PROTOCOL	MQTT	CoAP	XMPP	HTTP/RESTful
Transport	TCP/IP	UDP	TCP/IP	TCP/IP
Messaging	Publish/ Subscribe; Request/ Response	Request/ Response	Publish/ Subscribe; Request Response	Request/ Response
Cellular Suitability (1000s nodes)	Excellent	Excellent	Excellent	Excellent
Low Power and Lossy Network (LLN)	Fair	Excellent	Fair	Fair
Primary Orientation	Message	Web service/ Document	Message	Web service/ Document
Energy/ power needs	Low	Low	High	High
Key scenarios	Lightweight and embedded devices; unreli-able connections	Field; state-transfer; platform/network	Mass scale; persistent connections	Home and office

Source: Arlen Nipper, Graham Churchill, Electronic Design[18], Cisco Blogs[19]

Opportunities and applications of IoT in mining

The essence of the IoT is connectivity, data and analytics. The operations of many mining companies span from pit to port. They use machines that range from simple to complex and rely on workers who spend time underground and in air-conditioned offices. What opportunities could these companies realize if they were to connect everything (e.g., people and assets) and have the means to generate and analyze data of all kinds? As depicted in Figure 2, ultimately the most important questions are whether the IoT can equip miners to become better mining operators, whether it can combat current negative mining trends and whether it can assist the industry in its transition to a new period of productivity maximization (i.e., exploitation).

Figure 2: Challenges, opportunities and applications for IoT

CHALLENGES	OPPORTUNITIES	IoT TECHNOLOGY SOLUTIONS
Lack of R&D	Plant automation	Asset utilization
Rising costs	Energy and process optimization	Energy management eg. Ventilation, hauling and crushing
Declining labour	System integration	Predictive maintenance
Low commodity prices	Consolidation of systems and protocols	Inventory and asset tracking
Declining ore grades	Increased safety	Loss prevention
Insufficient infrastructure	Increased environmental knowledge	Integrated remote operations centres
Regulatory pressure	Mineral ore predictability	Geostability modelling and decision making
Low levels of exploration	Ore targeting optimization	

While the figure above points to a diverse set of challenges, opportunities, and solutions that are worth exploring, we will focus on some of the top-of-mind issues that our stakeholders believe that the IoT innovations can immediately address, and they are operational efficiency, enhanced safety, and integration.

Addressing productivity and efficiency challenges

"There are a lot of inefficiencies in batch process underground mining," says Symboticware's Kirk Petroski. "The utilization level for underground mining is at about 35% as compared to open pit or surface applications that are at maybe 70% or higher due to a more continuous process. If you're dealing with a valuable mineral... any nominal improvement in utilization will certainly help the bottom line." Simply put, the opportunity for optimization is huge.

"The real changes that have to happen are akin to what happened in manufacturing. Compare a car plant in the 1970s with the car plant that Tesla uses to build its new cars... there are sensors on everything today. There are robots doing everything. Mining today still looks like a car plant maybe in the late 70s, but not certainly not one in the 90s. Data are not fed together, and that's the key. That's what's got to happen," explains Glenn Ives. IoT systems with sensors, full data analytics, and automation capabilities will bring marked improvement to both mining productivity and efficiency just as it did for manufacturing.

A small example regarding fuel efficiency illustrates this point. Dick DeStefano tells us, "If you put sensors in a scooptram underground, and you put one on the seat and you put one on the motor, it will tell you how many people are actually sitting in the scooptram because of the weight. It will also tell you whether or not the guy has gone for coffee for an hour and has let the machine be idle—and you can shut it down [remotely]."

Image courtesy of pakorn at FreeDigitalPhotos.net

Addressing health, safety and labour issues

In part due to increasingly strict health and safety laws, miners are extremely focused on health and safety concerns. Coupled with the fact that they need to go further for ore deposits, a mining operation could grow risker over time. Vic Pakalnis says, "We've got a worldwide problem with fatalities happening at an alarming rate. Even though we're lowering the accident rates generally, fatalities tend not to be decreasing and are, in fact, increasing in some countries." By late October 2014, Australia's mining industry has suffered 14 deaths, which is almost three times as many as at this time in 2013.[20] "Here in Ontario, we've got quite a bad problem too. In fact, there's a provincial health and safety review that's underway, and one of the areas they're looking at is technology and the management of change," relates Pakalnis. For more information on this, see the Ontario Ministry of Labour's Mining Health, Safety and Prevention Review.[21]

The IoT can be manifested in vehicle collision avoidance systems, which include personnel and vehicle tags that can communicate wirelessly, and in trucks equipped with infrared, radar and video systems, all for the purpose of notifying operators of the presence of obstacles.[22] In addition, Schneider Electric suggests that miner safety could improve

with using the IoT to integrate "people tracking, communications, video surveillance and analytics, and real-time personal health management."[23] That said, perhaps another way to address health and safety concerns is to simply remove people from the front-line operations. BHP Billiton Ltd. recently outlined its intentions to switch to driverless trucks as a key to accomplishing its productivity goals.[24]

Integrated solutions for all miners

The integrated nature of IoT solutions means that mining companies can seize all of the opportunities at once. The driverless trucks initiative of BHP Billiton will not just help improve safety, but it will increase productivity as the trucks will be operational for more hours. How? Part of the answer is predictive maintenance. C. Prasanna Venkatesan notes that the solutions of Cisco and its partners can provide "failure predictions up to two months in advance with an 85% confidence interval so that preventive action can be taken." This will result in less downtime and fewer disruptions to mining operations. Dr. Joerg Benndorf argues that all of the technologies that have matured over the past 10 to 15 years and get deployed today will make mining more efficient, safer and more environmentally friendly overall.

The following are three prominent cases that demonstrate the results and potential of the IoT in mining across the globe:

1. Dundee Precious Metals launched an initiative called "Taking the Lid Off" that used IoT solutions to revitalize its flagship Chelopech gold mine in Bulgaria. The results of the initiative were impressive. The firm managed to quadruple production from 0.5 million to 2 million tons by tracking the location of miners and vehicles, monitoring the status of vehicles, automating building controls and utilizing software that could map, model, estimate, design, schedule, simulate and manage production based on the real-time data that the IoT system generated. This is perhaps the best known example in Canada. It was featured in the Globe and Mail in late 2013, and was highlighted in Cisco's IoT initiatives as well.[25,26,27,28]

2. Rio Tinto established the program, "The Mine of the Future," an undertaking that aimed to develop five different automation technologies. The program includes driverless trucks, driverless trains (e.g., AutoHaul), autonomous tunnelling and boring machines, a remote operations centre, and airborne exploration drones. Rio Tinto currently has more than 30 driverless autonomous mining trucks operating in the Pilbara mine. The trucks are controlled from a Rio Tinto Remote Operations Centre far away in Perth. In June 2014, Rio Tinto announced that its fleet of autonomous trucks had moved 200 million tons of material. By October, at the 2014 Internet of Things World Forum, John McGagh, head of innovation at Rio Tinto, stated in his keynote address that the figure had increased to 300 million tons.[29,30,31]

3. In 2008, the European Commission launched the EU Raw Materials Initiative (I²Mine) for the purpose of increasing the sustainability of the raw material supply, boosting efficiency and promoting recycling for underground mine operations. The project involves 26 participants,

including companies, research institutes and universities. One example of its IoT research and technology deployment is a set of sensing and control systems for autonomous machines. The set comprises an automated boundary layer and material detection system, a collision-avoidance and navigation system, an automatic guidance system for positioning and cutting, and an integrated, modular system for process optimization. This combined system resulted in a 17% improvement in efficiency and a 20% reduction in costs for deep deposits mining production.[32,33]

More and more, mining companies are seriously considering IoT solutions, and in particular, real-time monitoring. For example, both BHP Billiton and Vale opened remote operation centres. Jimmy Wilson, President, Iron Ore at BHP Billiton, asserted that accordingly, the company could see its total supply chain, in real time and in one place, enabling it to proactively make the right decisions for the whole business for the first time.[34,35]

The data on productivity maximization and health and safety benefits will continue to grow and create a strong case for widespread implementation.

Will Canadian mining fall behind?

Without a doubt, there are strong cases that support the adoption of the IoT in mining. While the benefits appear to strongly favour IoT adoption, we need to consider that the question of adoption tends to vary from company to company, and that the mining sector as a whole lags behind other sectors of the enterprise market (e.g., manufacturing). "There's a small handful of very large mining companies that have been, in recent years anyway, very progressive in adapting technology," observes Heather Ednie, Managing Director at the Global Mining Standards and Guidelines Group (GMSG). Almost all of the stakeholders we spoke with acknowledged that mining companies are as a group risk-averse and very cautious when it comes to adopting new technology. If one were to view the IoT market for the mining sector through the lens of diffusion of innovations, a theory popularized by Everett Rogers, all signs point to IoT as solutions that are attracting only innovators at the moment (especially in Canada), which is roughly 2.5% of a given population.[36] Glenn Ives recounts how the success story behind Dundee Precious Metal's IoT implementation came to be. He explains, "they pulled together their system because they had a very innovative mine manager who went out and looked for pieces to pull together. It was a bespoke system. They basically created it by pulling pieces of technology from everybody else."

The risk for Canada, a traditional mining powerhouse and globally a top metals and minerals producer, is that the country could fall behind and lose its leadership position if the industry collectively fails to leverage technology such as the IoT. And the exclusion of ICT technology in mining is not the only limitation: so is declining investment in mining research and development. Australia has

invested more than four times as much in research and development than Canadian firms, which has led to a growing gap in research competitiveness and technology uptake over the last decade.[37,38] Andy Reynolds has similar observations regarding Australian mining, though he cautions that one should not draw immediate conclusions about Canadians' willingness to innovate. "The real powerhouse in mining innovations is obviously Australia, and the amount of investment, teamwork and commercial effort that has been poured into the mining sector there is impressive. It hasn't been universally successful, but there are some notable success stories," says Reynolds. "It is something that we struggle with across many sectors. It is the balance between risk and reward. Adopting technology does require taking risk, and you have to take risks to compete."

Challenges with technology adoption

Aside from the common feeling that the industry as a whole respects tradition more than innovation, many of our stakeholders reflected on the particular question of Canadian mining companies' reluctance to adopt and deploy IoT solutions (or technologies in general). While the issues in play may not be solely Canada's, they are ones that do affect the Canadian mining sector. Of the industry stakeholders we spoke to, opinions on this subject tended to fall into several categories, described below.

CULTURE AND WORKFORCE

An interesting theme that emerged through our research is the major role that culture and workforce play. "The dramatic changes in technology don't seem to be quickly accepted because of the historical union management relationships. Older workers who are working underground don't want to change the pattern," relates Dick DeStefano. "In many cases, resistance is not to the equipment itself, because they think it's safer, but to the whole change in behaviour." Graham Churchill of IBM adds, "A lot of people who come up through the world of mining have come from a very specific background. They've been out in the field in one way or another and there is a 'we've always done it this way' attitude." Despite isolated incidents of adopting new technology, there is also a worry that mining companies are not being served properly. "Engineering companies are still designing based on old technologies because they haven't taken the time to learn about new technology," states DeStefano.

UNDERGROUND/DEEP MINING

More than a quarter of mining in Canada occurs underground.[39] Many believe this represents a unique challenge for technology adoption, especially in building an IoT communication network. Marc Boudreau, President and Co-CEO of BESTECH, explains,

> **"7,000, 8,000 feet—that's like having four CN Towers stacked on top of each other. When you get underground, there's a network of tunnels, and you could think of it as roads. The whole of downtown Toronto is really what it looks like underground on one level. That level is duplicated every 200 feet, and that's what we're dealing with. It's like trying to put a network in downtown Toronto in all the streets."**

"None of them have an infrastructure that reaches the entire mine," says Heather Ednie. So getting ready for the IoT, providing networking, and enabling real-time data underground will definitely require significant investments. However, the energy savings promise to be particularly lucrative for underground operations with reductions of 30% to 40% possible, and automated options that include ventilation, hauling, drilling and mobile plant.

WEATHER

It is not hard to appreciate the challenge of adapting technology that was designed to work in warm climates to meet the demands of harsh Canadian winters. (Anyone who has tried to operate a touchscreen with heavy gloves on will appreciate the challenge.) Vic Pakalnis believes innovators and entrepreneurs need to be particularly mindful of working with "infrastructure and technology that can withstand extreme cold and the situations that we find in the north." He cites the Ring of Fire region as an example, where extraction will occur in very remote areas with extremely cold temperatures.

SYSTEMS THINKING

A key challenge that Andy Reynolds repeatedly articulates is the need for mining companies to adopt systems thinking, enabling them to think more actively about technology management and to communicate those requirements at a higher level.

> **"Traditionally the mining industry doesn't regard itself as being an operator of a system. It seems to regard itself as being the operator of equipment,"**

says Reynolds. "Instead of saying, 'I want that truck', they [need to] say, 'I want to move this much material from here to here.' Then we'll start seeing more innovation in that whole supply chain. Then we'll see the missing piece in this, which is the role that the defence industry has undertaken for the military by creating systems integrator companies. This is a commercial evolution in the equipment supply chain that becomes necessary when technology really matters."

GOVERNMENT POLICIES

Some stakeholders also question whether the Canadian government is doing all it can to support mining in Canada. The industry is one of the country's principal wealth creators and job creators for Canada's First Nations. The uncertainty about its commitment remains despite an announcement in January 2014 of $15 million of funding that was awarded by Greg Rickford, then Minister of State (Science and Technology), to the Centre for Excellence in Mining Innovation (CEMI) for its Ultra-Deep Mining Network. (The grant came through the Business-led Networks of Centres of Excellence program).[40] "Government has to realize that if mining in Canada is going to survive and thrive, it needs to invest in our future as well—in the people, technology and research. The federal and provincial governments have not invested at the levels that they should. At the 2014 Energy and Mines Ministers' Conference (EMMC), the president of Lawrence University said the grants for research in dead languages and library archivists were on par with mining research," says Vic Pakalnis. He noted that in Australia, 25 cents per ton of mined coal is mandated to go toward mining research.

INDUSTRY RESEARCH AND DEVELOPMENT

While the Canadian government's support for mining is uneven at best, the mining industry itself can also do much better. Dr. Omid Mahabadi says, "The biggest [challenge] is probably the status quo [with respect to] to bringing in new technology. Especially with mining, they're not doing a lot of research, so they're not really familiar with trying out ideas.

Oil and gas do a lot more... Almost all the oil and gas companies have huge R&D budgets that they can work with." He is absolutely right. According to Mark Cutifani of Anglo American, the mining sector spends 80% less on technology innovation compared to the oil and gas sectors.[41,42] Heather Ednie has strong insights on this issue and comments, "Mining tends to be very shareholder-driven and [oriented to] short-term thinking because it's such a cyclical industry, driven by commodity prices. Every time the prices drop, companies cut back, usually starting with the technology and innovation department."

According to Ednie, most of the mining research is done through partnerships with universities, research hubs, suppliers, or even collaboratively among the companies themselves. Ednie relates that "there are a few mining companies that have large research and development budgets, but I remember 10 to 15 years ago, many of the research centres closed at major mining houses. Many mining companies in the 90s would actually have R&D centres. They're pretty much all gone."

This is almost the exact opposite of what the industry needs, as research from Dr. Joerg Benndorf and Dr. Mike Buxton shows that if the industry is willing to invest in new sensor technologies, **there are economic benefits to be gained at all stages of the mining cycle.**[43]

STANDARDS AND INTEROPERABILITY

With the IoT being fairly nascent, the issue arises of integrating both old and new systems and machines. Adding to this, industry groups, alliances and standards bodies abound. Kim Rowe, CEO of RoweBots, explains, "Most of them have really evolved in a collaborative way, but they evolved for different purposes from different industries. And so what we've got now is this huge fragmentation of protocols." However, whether the consortium is broad and technology-focused (e.g., the Industrial Internet Consortium, OASIS) or industry-focused (e.g., Ednie's GMSG), the main goals (with respect to operation and execution) are to ensure interoperability and proper integration. Indeed, as Ednie argues, "standards and guidelines are an essential ingredient towards enabling greater innovation in the industry." The lack of standards and integration is a primary challenge that the GMSG is working on: instead of having one shared GPS antenna, one truck will have nine antennae on it, because each control system needs to puts its own equipment in place. The key, of course, is to reach a point where IoT systems could be plug-and-play. "We've got to get to where that is the normal way of doing it. Then you can go and buy that. People [will have already] integrated it, and you're not trying to integrate it as you go," argues Glenn Ives.

Image courtesy of Stuart Miles at FreeDigitalPhotos.net

OPERATIONAL IMPERATIVE

For technology adoption in mining to succeed, it generally has to improve the bottom line or meet a mandated requirement. Mining operations have already been tweaked with the pre-IoT technology, so any new process must show a significant improvement above the status quo. With a strong but volatile outlook for the sector, the global mining and metals industry is focused on future growth

through expanded production, without losing sight of operational efficiency and cost optimization.[44] When a truck can produce $15,000 in revenue per hour, the loss of that truck for any reason quickly becomes very costly.[45] This is the same problem with any operational downtime, so a key imperative for technology vendors to road-test elsewhere and integrate products with as little interruption for customers as possible.

TECHNOLOGY RETROFIT

While a greenfield operation might seem the ideal condition to deploy new mining technology, the reality is that junior miners are struggling to stay afloat and a current lack of exploration exists. Given this, IoT adoption could well depend on how integration unfolds at existing mines. And this integration is much easier said than done. Arlen Nipper sums up the trouble: "It's naïve to think that [PLC manufacturers and mining companies are] going to go in and say 'okay, everybody tear out all of your legacy PLCs'." This is where the mining industry comes up short. "One of the most profound missing pieces [is system upgrade]. If you want to upgrade a mining system, it's very hard to do that because it was never intended to be upgraded," says Reynolds.

Canada's advantage: Ontario Network of Entrepreneurs and Sudbury

It is not easy to resolve or mitigate any of the challenges we've described. Moreover, different stakeholders must play their parts without fail in order to move the entire industry forward. Nonetheless, one cannot dismiss that Canada holds certain advantages that have accumulated by having been historically a dominant player in the global resources sector. Starting from a position of strength is a good thing. Northern Ontario, and in particular the Greater Sudbury Area, has an emerging underground mining technology cluster that is a global powerhouse. Indeed, it could be said that the Greater Sudbury Area is the Silicon Valley of mining technology and innovations.

> **"We are perceived by the industry based on the quality of the companies that we're working with"**

For decades, the primary industry in Sudbury has been mining. It has attracted many talented young researchers, engineers and entrepreneurs to the area. In a sense, it was natural for the community to stick with something that everyone knew well. Because the industry had longevity locally, businesses, knowledge and relationships had been built over time and were able to be leveraged. "We are perceived by the industry based on the quality of the companies that we're working with," says DeStefano.

None of the quality engineering and technology work is possible without excellent research and strong education programs. Within the Sudbury

mining technology cluster, there are a total of nine research institutes (e.g., CEMI, CAMIRO, MIRARCO). The university and community college system offers a plethora of mining-focused programs. According to DeStefano, a total of 75 programs from the colleges are directly related to mining. In addition, Laurentian University recently opened the Goodman School of Mines.

Organizations such as SAMSSA, Greater Sudbury Development Corporation (GSDC), and NORCAT, and the extended Ontario Network of Entrepreneurs (ONE), help connect and foster mining businesses. They provide funding, research and marketing opportunities at local, provincial and national levels through partnerships with the Federal Economic Development Initiative for Northern Ontario (FedNor), the Ontario Centres of Excellence (OCE), the NRC's Industrial Research Assistance Program (IRAP), and Export Development Canada (EDC), etc. Mining technology businesses also have opportunities to network with mining companies. "Sudbury has provided us with an opportunity to work with global mining customers first and foremost. Glencore and Vale are amongst the top five mining companies in the world. It's allowed us to work with these companies directly within a living lab, and then have them adopt the technology and further disseminate that out to other operations globally," says Kirk Petroski. Mining systems and equipment manufacturers and distributors such as Sandvik, Atlas Copco, Redpath and Toromont Cat all have a presence in Sudbury due to the local mining operations, expertise and experience.

According to a study by Doyletech Corporation that was commissioned by the Ontario North Economic Development Corporation, the cluster in Sudbury and the rest of Northern Ontario (e.g., North Bay, Timmins) contains approximately 500 companies (ranging from technology to services) employing over 23,000 professionals, collectively generating $5.6 billion annually.[46] DeStefano proudly affirms that many of these companies are doing leading-edge work. Aside from Symboticware, which does monitoring and data analytics, and BESTECH, which automates ventilation-control systems (see the profiles of these two companies later in this report), there are businesses commercializing and prototyping sensor technologies for gas leaks, robotics systems for underground mining, drones for surveying, advanced rock fragmentation analyses, and remote connected drilling.

Sudbury—and to a larger extent, Canada (Vancouver is also known for resource exploration expertise)—has the potential to further cement its leadership and authority in mining. Andy Reynolds of NRC envisions that Canada could develop "strong supply chains for equipment and systems, all the way through from entrepreneurs and technology developers to systems integrators to end users and their service companies." He sees mining and mining technology becoming "a sector of strength for Canada, a sector of industrial success and a sector where technological advantages reap real rewards." Perhaps with more industrial coordination, progressive government policies, organizational

Figure 3: Sudbury area as a mining focal point in Ontario

Recommendations for entrepreneurs

Before we present our research conclusions on the prospects of IoT in mining, we would like to share some of our stakeholders' ideas for technology entrepreneurs entering the mining industry. We want to draw attention to the concept popularized by economist Joseph Schumpeter that innovation is an exercise of creative destruction, where the new will replace the old for the better.[47] As Abraham Lincoln once said, "The best way to predict your future is to create it!" Therefore, if you are reading this as a new or scaling enterprise, consider the following as a set of ideas to use or try out.

Appropriate selling

It is accepted wisdom that the mining sector is risk-averse as a whole. But perhaps miners just view technology differently and require a different approach that allows new products and services to come through in a longer sales cycle. "Where we've spent a lot of our energy at Deloitte is essentially helping our clients think through the problem," says Bemal Mehta, Senior Manager of Deloitte Canada. Innovators and intrapreneurs may be naturally enthusiastic about a particular idea, but solution providers, companies and consultants alike need to think through all steps of the business case or use case. "I think that there is a misconception that these industrial players are backwards and they don't know what they are doing. All they are taking is resources out of the ground. Actually, they are very innovative on technology when they can actually see the benefits," explains Mehta.

Partner with the right players

The Internet of Things is multi-faceted and sufficiently complex that for a holistic solution to emerge at the industrial and enterprise level, many pieces would surely need to be put in place. If you are looking to sell a piece of IoT technology that more likely than not needs to work in conjunction with other assets or technology, it may make sense for you to partner with existing mining suppliers and service companies (e.g., equipment and networking companies). At that point, you will also likely need to understand and be prepared to work with all of the different technology standards and IoT/PLC/SCADA protocols. Therefore, participating or understanding the different consortia, trade groups, and standards organization is essential.

Pinpoint the proper systems

This report has highlighted systems thinking as a barrier to IoT adoption. Accordingly, we believe it is critical for technology companies to understand the systems. Andy Reynolds perceives "a lot of technology push going on, and a lot of advances being rebuffed by miners because they didn't realize that [technology vendors] were their systems integrators, and that there's an opportunity to have better integrated systems." Of course, the argument has two sides. As Reynolds explains, "Until the industry understands what the import-

ant attributes of the systems are, it won't be able to define requirements that innovators can meet." Understanding a mining company's operation from a systems point of view will enable more convincing arguments that your technology matters.

However, this is not the same as saying you should be selling a new system that replaces everything. "I've seen the smaller technologies being adopted faster, largely because of the risk profiles of these organizations. Large transformational changes are looked at with great caution," states Mehta.

Learn the industry

This may be a cliché. But given the traditional nature of the mining industry and the numerous challenges that it faces, it is paramount that entrepreneurs understand what is happening in the industry. (Tip: If you're in Canada, especially Ontario, Sudbury seems like a good place to start.) Building business cases and user scenarios will help you. Recognize that the industry is becoming more open. "We've also been working with other industries that have already solved the same challenges. Mining is unique, but we can definitely learn how it's been done elsewhere," asserts Heather Ednie.

Execute horizontally

Sometimes, it is important to go to where the action is as you work to realize longer term opportunities. Numerous growing enterprises within the ONE that we interviewed expressed interest to engage with clients outside of the mining industry, and some achieved success. In particular, the oil and gas industry, in which Canada is also a dominant player, has been faster at adopting IoT innovations. If your mining technology solution can easily be implemented and put to use in this industry, consider adopting a view and strategy for growth that involves the wider resources sector. If your technology can be truly scaled horizontally beyond the resources sector, you may even be able to capture a big slice of Canadian businesses' IoT spending, which is set to grow to $21 billion by 2018.[48] (To learn more about the different possibilities powered by the IoT and Big Data, see MaRS's **Connected World Market Insights Series**.)

Conclusions

In the short- and medium-term, the economic environment could remain relatively challenging for the mining industry. Given this, it is crucial for miners to leverage everything at their disposal to increase operational excellence and to continue to serve the global community's need for minerals and metals. For mining companies, IoT technology is close to being a "silver bullet." Whether a mining company is looking to decrease its expense or increase its output, IoT solutions can help.

A connected mining operation with integrated data is arguably a scenario toward which every mining company should strive in the next five to ten years. "[Integrated data] is going to drive the future of mining. Is [the operation] efficient? Is there some technology that can make it better? How many tons of ore did you produce? What's the metallurgy? ...How do you get the stuff to the surface faster? These are the kinds of issues that I think are important. I believe in mining intelligence and data," asserts Dick DeStefano.

While Dundee Precious Metals is a shining example of what's possible when a Canadian mining company deploys IoT solutions, as a whole, Canada's mining sector appears to lag behind its peers in countries such as Australia. Adoption barriers and challenges abound, but they are manageable. Moreover, there are plenty of innovative companies in Sudbury's unique mining technology cluster (and elsewhere in Ontario through the ONE), that have developed IoT solutions that are ready to be further validated or deployed immediately. And some of the biggest mining companies in the world have adopted these already. For example, one of these Canadian-made inventive solutions could reduce an underground mine's energy consumption by as much as 40%. You can read about the venture that has developed this product, as well as other innovative enterprises, in the company profiles section included in this report. Along with other stakeholders, these businesses can play a significant role in helping both Canadian and global mining companies reshape the future of mining.

It may take five, ten, fifteen years or more, but the IoT will arrive at Canadian mining sites. These mines will be connected, optimized, efficient, and far more sustainable than in the past. The opportunity is knocking.

COMPANY PROFILES

We interviewed seven companies that are playing distinctive roles within the Internet of Things technology landscape. They are offering their solutions to the mining industry and beyond. These companies are poised to grow within Canada, the United States and beyond.

We asked them 3 key questions relating to their products, competitive differentiation, and recent wins. Companies also answered a bonus question, so you can learn how different and unique their experiences are.

Kirk Petroski, President and CEO

Tell us about your company.

Symboticware was founded in 2008 and is based out of Sudbury, Ontario, operating in the technology epicentre of underground mining. We develop innovative technologies that are enabling today's industrial Internet of Things. Our technologies deliver the right data, at the right time, to the right people to drive the right business outcomes.

Symboticware's core product is the SymBot®, a monitoring and data solution that delivers standardized information-based technology that enhances the productivity, safety and efficiency of mobile and fixed assets. Our solutions leverage the customer's existing infrastructure and data reporting and visualization systems. Using open, standards-based solutions allows our customers to leverage their current investments and knowledge, while facilitating interoperability and ease of integration.

What distinguishes Symboticware from its competitors?

Looking at it from a mining perspective, there are solutions focused on fleet management and dispatch. These were designed to serve not only the mining industry, but also oil and gas. The challenge with these older systems is their closed approach to data beyond their own solution needs. In this new era of connectivity and data availability, customers are pushing back against this outdated approach.

At Symboticware, our goal is to disrupt these proprietary closed systems by unlocking the valuable data that already exists and can be used by customers to drive better decision making. Our approach takes a broader look beyond a single OEM [original equipment manufacturer] thereby enabling standardization across a typical mixed fleet environment.

What are your recent key wins?

The rate of adoption has been accelerated by the need to turn data into insight. While our foundation has been in mining, recent key wins include expanding our solution to additional industrial customers, including an oil and gas service provider and a global leader in off-the-road tires.

Tell us about some interesting challenges Symboticware has faced.

On the business front, we realized that no single provider of technology could deliver the complete solution. This led to an evolution in our industrial IoT strategy, with the development of a first-class ecosystem of partners, including Schneider Electric, OSIsoft, GE Intelligent Platforms, Toromont Cat, Wajax Power Systems, Valor TPMS and others.

On the technology front, pervasive communication and connectivity can still present challenges. We recognized early that underground mines and related areas do not have pervasive communication, which results in data gaps, manual data entry and subsequent inaccuracies in the data. Mines weren't getting real-time data—they were getting chunky data that was not trusted for decision support. We have a patent-pending store-and-forward algorithm that solves this challenge.

Marc Boudreau, President and CEO

Tell us about your company.

BESTECH is a multi-disciplinary engineering firm servicing the mining industry with offices in Sudbury and Timmins, Ontario. We also offer innovative solutions that enable mining operations to increase efficiency, reduce energy costs and improve worker safety. Our most revolutionary product, the NRG1-ECO, is a mine-wide ventilation control system that can save millions of dollars in annual energy costs. It adjusts a mine's ventilation system and reduces energy consumption by responding to the activity of mine personnel and vehicles, and the data from environmental sensors.

Ventilation is an important and complex system within underground mines and is also the largest energy consumer in a mine. Today, mines ventilate at 100% capacity, which means that all fans are operating 24/7. However, with our technology, a mining operation has the ability to analyze the underground environment and fine-tune the ventilation system to provide air when and where it is needed. In essence, it can turn the fans on to deliver the correct amount of required ventilation only to the zones of the mine where people and equipment are present. As mining companies dig deeper into the ground, the product is a useful tool when considering infrastructure development costs.

What distinguishes BESTECH from its competitors?

BESTECH's highly skilled team thoroughly understands applications related to mills, smelters and underground mines, and is well equipped to undertake a diverse range of projects. Our strategy is to provide innovative and cost-effective solutions that will satisfy our clients' needs. Our commitment to quality is manifested in the successful development and implementation of an integrated project management approach, superior engineering design processes, and our everyday communication with our clients. As a value-add feature, we offer ongoing support to ensure our products and services achieve the desired results. Our business isn't just about selling. It's about becoming part of the client's team and creating long-lasting working relationships.

With respect to the NRG1-ECO, the system has the capability to save 30% to 40% of existing current energy consumption by controlling the fans. As such, a mine site is able to reduce costs in the range of $2 to $4 million. We believe the system will have an impact on productivity in the mine as well. In the underground mine working environment, it is difficult to determine where people and equipment are located. Yet, with the use of radio frequency technology that is integrated in the NRG1-ECO, mining operations are able to quickly locate their employees and equipment. The other aspect of this technology consists of monitoring the air

quality underground, which enhances health and safety for miners as environmental hazards can be detected before they cause any harm.

What are your key recent wins?

Accepting new technologies in mining has been a constant challenge in the industry for many years. Industry players have had difficulty understanding the benefits and accepting the system in the mines. Therefore, the efforts exerted to continually improve the NRG1-ECO to better sell it to our clientele have been demanding. However, the funding we have received from various government organizations has enabled us to carry on our R&D work in order to bring our product up to the level it is at today. One funding program in particular, Sustainable Technology Development Canada, has been significant. It is a not-for-profit organization based out of Ottawa that provides support for proof of concept for technologies that will help with improving the environment. We have been able to reduce a great deal of carbon emission and energy consumption with NRG1-ECO.

How does BESTECH deal with different standards (e.g., networking, PLC)?

As mentioned earlier, relationship building is key in many aspects of our business. In the work that we do, many different networking standards and process control equipment exist, and they vary from client to client. Sometimes clients have preferred vendors and we have the ability and the commitment to work with any vendor. For example, the NRG1-ECO system can be configured to each mine's unique requirements and designed with an open interface that allows system integration with existing or new equipment. As a result, the NRG1-ECO can be customized to reflect each mine's needs and protocols in order to leverage the highest return on investment for each mine site. Our goal is to satisfy the client and we accommodate whatever standards they prefer. Our projects usually involve quite a few companies to deliver the desired results. We don't do it alone. We work as partners. That means we need to have great relationships with various associates, ranging from IT representatives to automation specialists to the actual construction labourers and electricians, in order to make it happen.

Kim Rowe, President and CEO

Tell us about your company.

What we really do is we provide technology to allow people to connect sensors to the internet. That's really what we do: we provide one-stop shopping. It could be hardware, software or an application. Our main product is something called the Unison operating system. And it looks like Linux except it runs on very tiny computers.

In mining, for example, we could actually be putting specialized sensors on mining vehicles. With specialized sensors, we can monitor different things and actually transmit data either over a satellite network, depending on where the vehicles are, or over a cellular network, so that somebody can actually track the vehicles. The data can help us to figure out what the productivity is and when the vehicles need service. We have a remote field service offering so we can update the sensors live in the field without sending a technician there. We also have all of the high-level protocols to organize about 500 trucks on a network and be able to track them all and have them registered and managed through a central system.

What distinguishes RoweBots from its competitors?

Minimal time to market and total cost of ownership differentiate RoweBots.

Time to market is minimized with off-the-shelf components for virtually all the various sensors, gateways and communications protocols required along with links to various host platforms. The open standards used ensure that lifetime costs are the lowest possible.

With respect to cost savings, you could build an asset tracker for $200, but if you use the right technology, you could probably do the same thing for $50. If you're going to do any kind of volume application, it really pays off for you to actually go and do the extra work if you can. If you are going to do 10,000 [units], 10,000 at $150 is worthwhile, usually.

What are RoweBots' key recent wins?

We do projects in the area of M2M [machine-to-machine] and have specific products for the resource industry (e.g., mining, oil and gas). But we are stronger in the areas of home automation, building automation and consumer gadgets. A large part of the heating ventilation and air conditioning equipment sold in North America uses our software, and furnaces in the southwest of the United States use our product too.

What are some trends you see with IoT technology?

Major trends are lower power and ease-of-use. Low power is really good. If you can do low-power wireless to monitor equipment and really push the power down, you could collect a lot of data—yet you could change batteries less often.

In terms of ease-of-use, I think that people are looking for faster and simpler solutions. That is certainly true for almost everybody doing sensors for the home automation market. However, I think the biggest trend is industrial [use of the IoT].

There's this huge potential because industry can make money with it instantly. And it's not the case of one customer thinking, "Oh, am I going to spend $1,500 putting a bunch of sensors in my home?" Rather, it's "Oh, I spend $1,500 and I get $50,000 back? Let's do that!"

Qwantech

Greg Hill, Technical Director *(left)*
Kevin Kuchta, Director of Product Development *(right)*

Tell us about your company.

Qwantech incorporated in 2009. One of our main products is a key performance indicator (KPI) system that uses real-time data from the frontline. We take a company's existing KPIs and provide a way to track, organize and display them. Generally, a consultant will work with a company to help it discover what KPIs should be of most concern, and from that point, we implement the tools that help them put those KPIs into place within the organization.

One of the pain points we've found is that organizations are often not using one unified set of databases or systems. They have quite a few departments or sites that are using different sets of software to collect data.

A lot of organizations with large systems have trouble engaging users or data at a departmental level, and conversely, a lot of departments collect good information that remains in a silo. It is difficult for a company to implement these KPIs on a day-to-day real-time basis when such fragmentation exists.

What distinguishes Qwantech from its competitors?

If a company is using one large system, SAP for example, taking KPIs and implementing them is generally an easier job. However, there is a universal problem when you have more than one consultant and vendor involved: everyone protects his or her turf and databases, and everyone has his or her own reporting system and procedures. Between management, staff and vendors, everyone is trying to be the all-inclusive package. Qwantech is a hybrid in between. It is not all or nothing. Companies can use our tools in conjunction with large systems, or even with fragmented systems from multiple vendors. We focus on adoption, user experience and getting accurate data.

What are Qwantech's key recent wins?

In terms of technical breakthroughs, we're proud that we can incorporate video within our KPIs. We have a video solution that adds real value to KPI and health and safety data gathering and measurement. As a business, and especially as a smaller northern company, we're proud to stand among larger companies and vendors and offer solutions that have received great adoption and feedback.

What's your impression of mining companies from doing business with them?

Mining companies want increased productivity. But in our system, better relationships with communities matter too because that's definitely a part of most mines' KPIs. Our system enables an organization

to track these relationships and make sure that they remain in good standing with their communities.

From a consumer level, mining has a bad reputation for a lot of issues such as safety, community relations and the environment. But we've found that there is no "Wizard of Oz" behind a curtain. In every room I've ever been in, I've never met a mine manager who does not care about the environment. For safety, I know the intention of all the organizations we've worked with is to be excellent. No one is trying to disregard or cover up the issues; empowering them with proper tools helps.

To sum up, it's not just about increasing production. The organizations we work with care about improving safety, the environment, happiness amongst their workers and the communities in which they work and live. We are happy that we can enable our customers to reach their goals.

Omid Mahabadi, Co-founder

Tell us about your company.

We're developing a computer simulation software, which is very advanced both in terms of physics and in terms of the computational engine. In the software, you specify input parameters related to the Earth such as rock properties, and then you can predict how the rock will deform, and if it's going to fracture, how it will fracture, and various mechanical properties about the rocks. The software makes predicting the rock behaviour a lot easier and a lot more accurate, and fast. It gives you the results very quickly—within a few hours.

The solution takes advantage of Big Data. The platform is very flexible. It can be utilized with a variety of datasets and computation models. Let's say it's database applications: you could use our library and do fast computations on the GPU. You could use a desktop PC with one or two GPUs in it, or you could have many parallel processors, or you could have a big giant infrastructure with many processors.

What distinguishes Geomechanica from its competitors?

There are few software companies in the UK and the US similar to ours. We are now in the range, in terms of the performance and speed performance, of what people call the standard in the field—but at the same time, the physics is a lot more vigorous. It is a lot more accurate.

Another advantage of ours is that you can see everything that is happening. The others will give you, say, a red colour, saying that this is an area where things may go wrong, whereas ours will show the actual fracture that is happening, and it shows you what will happen over time. Our product is also 3D and we have included space and time components.

What are Geomechanica's recent key wins?

While it's not in the oil and gas or mining sector as yet, we've been heavily involved with the development and design of the nuclear waste disposal system for Switzerland. That is also a great rock mechanics application because it involves drilling a few kilometres deep, and you want to make sure that you're not really changing the state of the rock too much. We've been involved for over three years now helping them understand what is happening as a result of drilling or tunnelling operations, and what are the consequences of their actions.

Can you tell us about a mining application for your product?

In terms of mining, the biggest one will be structural and stability analysis. For example, when you go into a cave, you can extract material from the ore body. Our application can tell you what will happen if something goes wrong, unlike other tools that only tell you if the structure is going to be stable.

Then there is tunnelling. We can again study the stability of tunnels and also the change the ground that surrounds an excavation. We can analyze the excavation damage zones and consequently optimize the amount or type of rock support needed.

David Peres, President

Tell us about your company.

Minalytix is based in Sudbury, which is one of the world's greatest mining technology clusters. Sudbury is like the Silicon Valley of mining. We see a lag between modern software technology and its adoption into exploration and mining. We are hoping to be the company to close or lessen that gap.

Currently, our key offering in the resources industry is custom software development to solve business problems related to mining and exploration. We also have a suite of software tailored for mining and exploration that is in production that will be released more widely in 2015.

We have worked on projects around the globe for exploration sites as well as open pit and underground mines. The business units we have worked with include exploration, mine planning, sustainable development, risk management, health and safety, HR, finance, mine operations, mill operations and smelter operations.

What distinguishes Minalytix from its competitors?

One of the repeated statements that we hear from many users of mining software is that they feel like they are working in the past. The systems that they use at home or in other areas seem faster and much more advanced, intuitive and reliable than what they are using during their workdays. We also hear many complaints over the current software licensing and distribution models in mining and exploration, as well as the high cost of purchase and implementation. These are key areas of potential differentiation.

We are also focused solely on mining and exploration software projects, which gives us a competitive advantage over most general software consulting firms. Our intimate and detailed knowledge of the specific processes and challenges in mining, milling and smelting gives us the ability and credibility to work with mining clients at any level. The founders combined have 26 years of mining industry experience.

What are Minalytix's recent key wins?

Minalytix has only been in business for 13 months. That said, we have been very successful at delivering high-quality solutions without defects and in meeting budgetary, schedule and scope demands. We have also been praised for doing more than just "taking dictation."

How will the Internet of Things change the resource sector (e.g., mining)?

We feel that with better integration and the removal of barriers in workflows related to inter-system communication, the resources sector could see large improvements both in time to market of products as well as in cost reductions. The time that it takes to find, prove and develop ore bodies could be greatly reduced. Being able to tie together data from the

various business units in a mining organization also helps streamline processes, provide management with the vision and tools that they need to make key business decisions quickly and correctly, and promotes overall efficiency and synergy within the operation.

Vatsal Shah, CEO and Founder

Tell us about your company.

The founders met in August 2013 and conceived the company. We function in the new Internet of Things and industrial automation ecosystem that allows businesses to not only visualize device sensor data, but also make business use of it by streaming data to their existing enterprise applications, databases or smartphone apps.

To deploy a solution with the Internet of Things, there are a lot of challenges at the hardware and software level, and there's a lot of upfront investment involved. We are trying to build a holistic solution for end-to-end cloud-based infrastructure and platform-as-a-service for the IoT. As a company right now, we have one product, a software platform, and it is called Litmus Loop.

Loop is a full-fledged Internet of Things cloud platform. The platform provides faster and more secure, scalable and flexible IoT communications.

What distinguishes Litmus Automation from its competitors?

First, we provide a system that does not store any data. Data just passes through our platform. That's a big advantage for those enterprises that do not want their data to be stored in anyone else's platform, and they can avoid any vendor lock-ins. Second, Loop is one of the first end-to-end solutions that connects devices to over 20 enterprise applications like Salesforce, SAP or Big Data solutions, or to their own databases. Loop has a proprietary data model behind it that enables seamless integration without writing a single line of code!

For companies that are just connecting their devices, there is minimal cost to using the platform. We barely charge them anything for connecting 100 devices or sensors. Additionally, companies can choose enterprise integration applications from our marketplace at a very basic cost. For larger projects, we have a licensing model that lets companies flawlessly scale their businesses.

What are Litmus Automation's recent key wins?

We currently have three Fortune 500 clients designing solutions using our platform. In one of our projects, our client will be providing seamless healthcare integration for every person and for different healthcare needs. A single platform, Loop will take care of connecting different assets, such as ambulances, patient monitoring, inventories from a hospital management system and certain non-predictive variables. In the healthcare industry, there are a lot of challenges like healthcare standards, and, moreover, government compliances for deployment. The project is massive and we are working with expert system integrators. Loop will be collecting data from various healthcare devices and making it available to different applications—a big win for us.

What is your perspective on the IoT phenomenon?

The entire Internet of Things industry is hot right now. It is the talk of the town. Early adopters think that the Internet of Things is all about home automation or connected cars. It is way more than that. There is a humongous amount of data coming from various devices, sensors or smart machines, and there are a lot of business opportunities surrounding it. The challenge is not only to gather this data, but to leverage it to make wise decisions. The whole Internet of Things ecosystem will be highly competitive and will have many players at every stage.

Note: This company has key executives based in Ontario, but its offices are located in the US and India.

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